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Soviet Software Productivity: Isolated Gains in an Uphill Battle

A Research Paper

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Soviet Software Productivity: Isolated Gains in an Uphill Battle

A Research Paper

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May 1990

Soviet Software Productivity: Isolated Gains in an Uphill Battle

Summary

Information available as of 1 March 1990 was used in this report.

The leadership of the Soviet software R&D community recognizes—as revealed in open-source literature—that the USSR's software industry is technically backward. The Soviets know that, if this problem is not corrected, Western countries will be able to extend their domination of advanced information-processing technologies for decades to come

We judge that software productivity now has reached crisis proportions in the USSR:

- Insufficient capital investment is crippling the software industry.
- Costs of maintaining obsolescent software are spiraling.
- Software developers are resisting industry standards and norms that could improve efficiency.
- The Soviet software industry has been slow to adopt new techniques and technologies.

By reviewing a large volume of open-source literature published between 1975 and 1985, we have identified Soviet plans to undertake a major productivity initiative to address the software crisis. Soviet materials published since 1985, [redacted] indicate beyond reasonable doubt that such an initiative is under way.

According to a variety of authoritative articles published in the Soviet literature, the goals of the USSR's software productivity initiative are to:

- Enhance the quality of systems software (used to operate computers) and applications software (used to perform particular tasks).
- Increase the variety of software products available.
- Reduce the rapidly accelerating costs of developing and maintaining software

The Soviet software initiative involves major reorganizations of, and capital investments in, science, education, and industry:

- Scientific research will focus on the development of software for advanced computer architectures—in particular, parallel-processor supercomputers—and on automated techniques for producing software.
- The Soviet educational system will turn out larger numbers of software workers.
- The USSR's fragmented software industry will be gradually integrated through a new national-level management system

In promulgating their software productivity initiative, the Soviets will get substantial benefits from emerging pockets of excellence in their software R&D community:

- The Soviet computer science community has developed a healthy capability to innovate software for highly parallel computers—supercomputer-class systems that have hundreds to thousands of individual processing elements that work in parallel. The Soviets by the turn of the century may be at or near the Western state of the art in this research.

- The Soviets have applied artificial intelligence (AI)—"expert systems"—to support space operations and, in some areas of AI, research may approach the West's level of achievement by the end of the century.

- Soviet researchers have mastered a variety of techniques for the automated production of software. Industries supporting military R&D and production are likely to be the first in the USSR to assimilate such new technologies—particularly to manufacture new microelectronics, optics components, inertial instruments, and other precision equipment.

- Soviet scientists have developed software for a number of industrial applications that Western sources have described as as good as, or better than, analogous software in the West

Fruits of the USSR's software productivity initiative, coupled with the output of emerging pockets of excellence, will give the Soviets important new military and economic capabilities in the years ahead. The software R&D base the Soviets will have in place by the late 1990s should approximate that available in the West in the late 1980s. The availability of such a base will underpin the development of software-dependent weapons, reconnaissance systems, communications, and logistic systems that will be deployed by the Soviets early in the next century

As the Soviets press ahead with their software productivity initiative, we expect them to intensify their efforts to obtain foreign software production technologies and know-how. The changes now unfolding in the USSR and Eastern Europe undoubtedly will increase Soviet access to Western software technologies; efforts by US and West European software developers to engage in joint ventures with the Soviets are increasing and probably

will continue to grow. Furthermore, the growing number of countries that are capable of developing commercially successful software industries (for example, Brazil, India, South Korea, and Singapore) are not necessarily disposed toward international regimes to restrict the flow of technology to the USSR or Eastern Europe

In spite of the considerable talent and effort the Soviets will apply to their software productivity initiative, we doubt that the USSR will be able to close the roughly 10-year gap between it and its foreign competitors by the turn of the century. Most likely, the Soviets will be hard pressed to keep the gap from widening as Western progress accelerates. The Soviets will be constrained by:

- Their lack of experience in operating customer-oriented businesses.
- Management philosophies that reward the maintenance of existing product lines at the expense of new products.
- The lack of computer hardware and a telecommunications infrastructure that would be vital to a modern software industry.

Failure to close the software gap will keep the Soviets at a significant disadvantage in competing with other countries in the development and production of advanced weapons and military support systems

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Software Productivity: Technical Crisis in the USSR

The leadership of the Soviet software R&D community recognizes—as revealed in open-source literature—that the USSR's software industry is technically backward. The Soviets know that, if this problem is not corrected, Western countries will be able to extend their domination of advanced information-processing technologies for decades to come. Despite the Soviet experts' grasp of the issues and good understanding of what it would take to resolve them, we judge that software productivity now represents a crisis facing the Soviet S&T establishment at large.

The USSR's capability to develop and maintain advanced computer software is substantially affecting the degree to which it can compete with other countries in the development of advanced weapons and military support systems. Software engineering expertise is particularly critical to developing and operating survivable, fault-tolerant command and control networks. Advanced software is vital for the computing required for modern aircraft, missiles, and intelligence collection systems. The design, development, and efficient production of weapons is increasingly dependent on advanced software. The Soviet intelligence services need software technologies that facilitate "smarter" automated data-base management in order to process the ever-increasing demand for global intelligence.

Insufficient Capital Investment

According to open-source literature, Soviet software experts believe that the relatively insignificant capital investment in new technologies by Soviet software engineering enterprises—equivalent to some 3 percent of the total annual cost to capitalize and operate a given enterprise—is crippling the USSR's software industry. For example, V. V. Lipayev—a leading Soviet authority on software industry capital investment strategies—contrasts this minuscule annual capital investment with the roughly 15- to 40-percent annual investments in production technologies typically made by other Soviet high-technology industries.

Spiraling Maintenance Costs

The Soviets face spiraling costs to maintain increasing stocks of obsolescent systems software and applications software. Servicing the inventories of obsolescent or obsolete software requires that the USSR maintain large industrial organizations to inventory, document, install, upgrade, and debug each product. Soviet industry also must train annually tens of thousands of workers from user organizations on existing software—diverting scarce resources from the development of new, more efficient software products.

According to Soviet open-source literature, as much as 60 percent of what we estimate to be about a $27 billion Soviet investment in developing, manufacturing, distributing, and maintaining information technologies (hardware and software) is attributable to or driven by software. According to the same Soviet open sources, some 70 percent of the output of the USSR's software R&D and industrial infrastructure is directed toward maintaining existing products in service (principally debugging and modifying code and documenting the improvements)

Our analysis of information in the open literature indicates that annual maintenance expenditures for software products in the USSR probably can be reduced from 70 percent of annual software R&D/industry operating costs now to perhaps 60 percent in the late 1990s. In the United States, Western Europe, and Japan, on the other hand, analogous product-maintenance costs probably will be brought down to 50 percent of total annual costs by the year 2000. The Soviets cannot escape the requirement to maintain a large inventory of obsolescent software for 1970s-vintage IBM and Digital Equipment Corporation

computer systems; this requirement will reduce the pace at which the USSR's software industry can shift resources from maintenance to R&D.

Resistance to Standards and Norms
According to a variety of open-source reports, software developers in the USSR resist efforts to impose rigorous, quantifiable norms and performance indexes and standards that could be used to plan efforts, predict performances, adjust for problems and delays, and quantify individual or team performances—despite the existence of such national-level standards as the USSR's Unified System of Software Engineering Documentation (YeSPD). Soviet experts (like their counterparts in the West) insist that opposition to structured, quantifiable management has been a principal reason why software often costs too much, does not meet prescribed qualitative expectations, and requires major maintenance or fundamental reworking after installation at customer sites

The failure to apply or enforce the use of standards such as the YeSPD is part of the reason for the poor quality of software product support (maintenance) rendered to computer users in the USSR, according to reports from a variety of open sources. The software maintenance community is inefficient by Western standards, despite the existence of an extensive network of product "service centers" located in cities all over the USSR. Because of a lack of real competition and profit incentives, there has been little if any reason for software developers in the USSR to warranty or otherwise service products. According to our analysis of open literature, maintenance by the Soviet software developer or vendor after the customer has purchased the product is typically poor

Little Commitment to Intellectual Property Rights
Although [redacted] and open-source literature indicate that the Soviets understand the importance of according intellectual property rights—copyright protection—to software technologies, it is clear that the USSR is reluctant to make the legal commitment to this concept. The considerable reluctance by the Soviets to accept capitalist concepts of copyright protection inhibits software productivity within the USSR, as well as software-related R&D, manufacturing, and distribution agreements with Western firms.

Resistance to New Techniques and Technologies
The emerging software industry in the USSR also has been reluctant or unable to use new "tools of the trade"—software production techniques and desktop microcomputer workstations—that are becoming vital to increasing efficiencies within software industries in the United States, Western Europe, and Japan. The production techniques, called CASE (computer-aided software engineering), are specialized types of software used to design and build other types of software. Soviet software developers have demonstrated ingenuity in developing innovative CASE technologies that may have the same level of functionality as analogous products marketed in the West. Nevertheless, working levels of Soviet industry appear to be successfully resisting the use of the new techniques and technologies, which they view as disruptive to previously planned production.

Computer Hardware and Telecommunications Deficiencies
The USSR is struggling with limited success to acquire and put into use the computer hardware that would be vital to a modern software industry. The Soviets are engaged in efforts to acquire, via domestic production and massive imports, tens of millions of personal computers (PCs). The Soviets also are deficient in the production and effective use of larger scale computer resources (minicomputers, mainframes, and supercomputers), as well as the means to establish and maintain reliable national telecommunications networks enabling users of such equipment to work together from remote locations all over the USSR.

The telecommunications deficiency is a particularly serious problem for the Soviets. The USSR lacks the type of extensive, serviceable, open-access, civil telecommunications infrastructure that has proved to be an essential ingredient in the US software industry's capability to support the needs of software users in all sectors of the US economy. Technologies critical to the US industry's lead include wide-area networks—such as INTERNET, TYMNET, and TELENET—accessible to most software developers in the United States; equally important are the local-area networks

used to connect software development teams distributed in different locations within large buildings or among several facilities within a large industrial park.

Addressing the Problem

By reviewing a large volume of open-source literature published between 1975 and 1985, we have identified Soviet plans to undertake a major software productivity initiative. Soviet materials published since 1985, [redacted] indicate beyond a reasonable doubt that such an initiative is now under way

The USSR's attack on the software productivity problem is in large part the result of the efforts of a group of influential computer scientists and mathematicians with good access to S&T and economic policy makers in the USSR Academy of Sciences, various State Committees, and the Council of Ministers—and of the economic reformers in the Politburo. Analysis of data that reveals the creation of "blue-ribbon" scientific commissions, as well as an upsurge in S&T conferences devoted to software engineering and applications, indicates that in the late 1970s this relatively small but influential elite convinced the Soviet S&T leadership to sponsor long-range plans to mitigate the impending software productivity crisis in the USSR

A key indication that the USSR implemented a software productivity initiative at the outset of the 12th Five-Year Economic Plan (1986-90) was revealed in General Secretary Gorbachev's January 1986 report to the 27th Congress of the Communist Party of the Soviet Union. According to Gorbachev, for the period up to the year 2000: "Specific targets have been set for the development and mass assimilation of computer technology including computer software. . . ." This and subsequent pronouncements made by the leaders of the USSR's computer science and industry establishment all but confirm the existence of a national-level R&D strategy (what Soviet spokesmen commonly refer to as a "unified scientific-technical policy") for software research, development, production, and maintenance in the USSR. The strategy is being managed by the State Committee for Computer Technology and Informatics (GKVTI), headed by B. L. Tolstykh.

We believe that the Soviet S&T leadership does not think that success in their software productivity initiative will necessarily provide the USSR with a world-class software industry. More likely, the Soviets have concluded that their initiative offers the USSR at least a fighting chance to prevent a marked increase in the West's approximately 10-year lead in widely exploiting state-of-the-art software technologies for practical applications to national security and general economic challenges.

Goals

According to a variety of authoritative articles published in Soviet open-source literature during the period 1984-90, the prescribed objectives of the USSR software productivity initiative are:

- To enhance the quality of systems software (used to operate computers) and applications software (used to perform particular computational tasks) delivered to consumers in all sectors of the national economy.
- To increase the variety and production of software products available.
- To reduce the rapidly accelerating costs of developing and maintaining software.

Implementation

Successful accomplishment of the goals of the USSR software productivity initiative will involve major reorganizations of, and capital investments in, the three sectors of the S&T establishment—science, education, and industry. The plans for each sector include:

- *Science.* Reinforce financially those elements in the science sector that provide the fundamental (exploratory) and applied (goal-oriented) research on CASE techniques and technologies.

- *Education.* Build the academic infrastructure necessary to educate and train the hundreds of thousands of systems analysts, software engineers, and programmer-technicians needed to manage, develop, and maintain all types of computer software in the USSR.

- *Industry*. Reorganize and expand the USSR's fragmented software industry into an integrated institutional base that develops, manufactures, and services computer technologies of all types and for all consumers.

According to open sources, the Soviets plan to increase annual capital investments in their software R&D/industry infrastructure from the equivalent of some $200 million in 1988 to about $1.65 billion in 1991. This increase reflects a focused effort to more equitably capitalize the USSR's software R&D industry infrastructure. We believe that the planned investment for 1991 will constitute about 10 percent of the estimated annual cost—equivalent to some $16 billion—to operate the hundreds of scientific, academic, and industrial enterprises and industrial associations that make up the USSR's software R&D industry.

The Role of Science. Authoritative Soviet writings indicate that the USSR and republic-level Academies of Sciences will act as the technical spearheads of the software productivity initiative. Scientific research will be focused on techniques and tools to develop systems software for a variety of advanced—for example, parallel processor—computer architectures, some of which have no direct counterparts outside the USSR

The most important facet of the advanced architectures challenge involves research on software for innovative supercomputer architectures—critical to Soviet progress in military R&D. The Soviets are focusing considerable research as well on means to apply artificial intelligence techniques to enhance software productivity

One of the general trends in Soviet computer R&D that will substantially influence the focus of exploratory and applied research for future software is the gradual shift away from serial processing to parallel-processing computer system architectures. This trend, begun in the late 1970s, is based largely on innovative research on parallel-processing hardware and software carried out in the USSR since the early 1960s.

An aim of the scientific research program supporting the Soviet software productivity initiative is to standardize computerized techniques and technologies that will be used to implement CASE environments. Much of this research is focused on employing means to improve the efficiency of the first phase of software development—requirements analysis—where problems in communicating ideas between developers and customers propagate subtle "errors of omission and commission."

The Role of Education. The USSR's software education effort will play a pacing role in Soviet efforts to automate industry, raise the quality and quantity of goods and services, and better compete in international trade. Software engineering training and education will be critical in the Soviets' efforts to develop the increasingly sophisticated and costly weapons, sensors, and other systems that they believe are needed to maintain military parity with potential adversaries.

The Ministry of Defense (MO), the KGB, and the Ministry of Internal Affairs (MVD) probably will be particularly forceful proponents for enhancing software engineering and programming education if for no other reason than to ensure that the armed forces, intelligence community, and militia need not rely too heavily on the USSR's civil-scientific community to provide software for sensitive national security purposes. The MO, in particular, must cope with the bleak prospect of having far too few software-qualified technicians to service an increasing variety of computer-dependent arms and other materiel—a problem likely to worsen in the 1990s if the most qualified software professionals in the USSR gravitate toward employment in the civil sector. This shortage is already making itself felt as increasing numbers of the best Soviet software engineers are focusing on pursuits that enable them to earn money in international joint ventures and to travel abroad extensively.

The Soviets' objectives by the mid-1990s are to have tens of thousands of new systems analysts and software engineers, and by the end of the century

hundreds of thousands of new programmers could be added to the work force—supplementing the 300,000 to 400,000 software development personnel reportedly working today in the USSR (versus an estimated 700,000 in the United States). If educational objectives are met, the USSR could have about a million trained software workers by the year 2000. This number is still far short of US industry estimates of 3 million software professionals employed in the United States in the year 2000. Moreover, although the USSR can almost certainly generate a population of at least a million software workers by the end of the century, the vast proportion (in excess of 85 percent) are likely to be programmers with limited skills; systems analysts and software engineers, who are educated to master more difficult and technically challenging tasks, will remain in short supply.

The Role of Industry. A review of Soviet open sources, [ ] indicates that the Soviets will work to evolve a modern software industry through the 1990s. The software industry effort also will promote extensive collaboration with advanced research organizations (in the scientific sector of the national economy) responsible for proving the feasibilities of emerging software-engineering technologies.

We believe that the Soviet software industry—faced with the simultaneous challenges of modernizing its obsolete product engineering and manufacturing base, and meeting accelerating demands for a proliferating variety of new products—will avoid risk taking and remain conservative insofar as capitalizing high-cost software engineering technologies is concerned. The software R&D leadership in the USSR recognizes this productivity damping tendency and is taking every opportunity to offset it by promoting closer ties between the software engineering research community and industry. The overall strategy seems to be to expand the involvement of CASE developers (largely in the research community) and to accelerate a measured introduction of CASE technologies in accordance with the concerns of real-world industrial users.

In April 1988 a new concept of software industry for the USSR was codified as the State System for Software (GSPO)—a national-level administrative body intended to establish connectivity throughout the USSR's software R&D infrastructure. The GSPO, to be responsible to the GKVTI instead of the industrial ministries such as the Ministry of the Radio Industry (Minradioprom), is being established as the national-level management system for the USSR's evolving software industry

Protecting Intellectual Property. Although the USSR thus far has moved slowly in terms of changing its legal philosophy to accommodate protection of intellectual property such as software, there are signs that the party and government bureaucracies are moving in the right direction. Over the past year, high-level commissions, such as the State Committee for Science and Technology (GKNT), have begun to engage Western counterparts, such as the US National Science Foundation, in substantive discussions that reflect Soviet acceptance of the need to adopt copyright laws applicable to their own as well as foreign technologies and products. USSR Academy of Sciences experts—some of whom stand to gain small-to-moderate fortunes by means of their participation in software "cooperatives" or East-West joint commercial ventures—are using their considerable influence to push the Soviet bureaucracy toward affording copyright protection to domestic and foreign software.

There is a better-than-even chance that, over the next two to three years, the USSR will implement copyright protection to software technologies and products and that such legal codifications will be consistent with internationally accepted norms. Whether the Soviets choose to enforce these copyrights is another matter. On balance, we expect that the USSR will not enforce copyright laws on foreign-origin software technologies or products introduced into the Soviet domestic economy any better than do countries such as Brazil, India, or Thailand—all of which do

little to police domestic industries that pirate products copyrighted by software companies in the United States or Western Europe.

Emerging Pockets of Excellence

The increasing number of Western experts (programmers, software engineers, computer scientists, computer systems developers, software industry marketeers, and production managers) who have gained access to the CEMA software R&D infrastructure and industries since the mid-1980s have been impressed with the technical skills and innovativeness demonstrated by their Soviet and East European counterparts, and unclassified US and West European trade literature. As the Soviets work to modernize their military and civilian industries, these emerging pockets of software excellence will make positive contributions.

Since 1987, when the Soviets enacted new laws to facilitate joint commercial ventures with foreign industries, software R&D entities and industries in the United States, Western Europe, Latin America, and in the Pacific Rim/southern Asian region have enthusiastically engaged the Soviets in negotiations to make commercial use of the large pool of software engineering and programming talent located in pockets all over the USSR. This interaction has since led to a proliferation of bilateral and multilateral business ventures in which the Soviets barter the skills of their programmers and software engineers—including some of the best in the USSR—in exchange for what the Soviets need desperately—large quantities of microcomputer (PC) hardware and hard currency. The increased interactions of East-West software R&D and industry experts have made available for the first time to Western industries a variety of Soviet-origin applications software products, which some US and West European firms believe can be marketed successfully in the West.

Parallel Processing

Western sources have come to recognize that the Soviet computer science community has developed a healthy capability to innovate operating systems and applications software for highly parallel computer systems incorporating relatively sophisticated concepts of artificial intelligence (for example, data flow operating systems integrated with neural-network designs). Moreover, the Soviets seem to be spending a considerable effort in developing software engineering tools specifically oriented to generating the extremely complex applications software necessary to take full advantage of parallel-processor computer systems. Analysis of all available sources indicates that the Soviets are mobilizing their software engineering research effort to develop operating systems software (such as for highly parallel data flow concepts) that can compensate for the obsolescent microelectronics (microprocessors and logic chips) that have stymied Soviet efforts to manufacture high-speed computers. Some of this Soviet (and East European) software engineering research for parallel processing paces similar research at leading Western universities and corporate research centers.

The potential pockets of excellence in software engineering in the USSR and Eastern Europe for parallel-processing applications involve the efforts of a variety of scientific and academic establishments that have strong ties to the military and intelligence services. supplemented by open-source literature:

- The Ukrainian Academy of Sciences Institute of Cybernetics *imeni* V. M. Glushkov (Kiev) operates special computer technology and software engineering development centers in conjunction with defense industries.

- The Estonian Academy of Sciences Institute of Cybernetics (Tallinn)—with ties to the KGB—develops software for supercomputer testbeds and highly parallel processors.

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- The Slovak Academy of Sciences Institute of Technical Cybernetics (Bratislava, Czechoslovakia)—a focal point supercomputer research institute in CEMA—has both ties to the West and a strong tradition of collaboration with research teams at the Soviet Glushkov and Kalmykov institutes.

Artificial Intelligence

An example of Soviet competence in software R&D is the development of rule-based inferencing tools for data bases, or "expert systems"— first-generation AI software packages—used to support space-launch operations. According to a variety of sources in open literature, these technologies were implemented in the mid-1980s a few years after the United States began to master AI software technologies for application to space operations. Analysis of these sources indicates that the USSR Ministry of Defense is using several different expert-system ("human apprentice") software packages with the Energiya (SL-X-17) heavy-lift launch vehicle and the Buran shuttle-orbiter. Intelligence Community assessments conclude that the Energiya/Buran system will be used to deploy key Soviet national-security-mission payloads in the 1990s.

The Soviets resorted to the use of rule-based inferencing expert-system software with the Energiya/Buran launch-control system and the Energiya fueling system to minimize the possibility that human oversight or error, or equipment failure, could culminate in destruction of the launch vehicle and its various payloads on the launchpad. According to the open-source literature describing this AI software, these rule-based inferencing packages are capable of identifying and responding to a problem faster than a human. The AI software used with the launch-control system, which reportedly can compensate for nearly 150 different types of faults, automatically canceled the Energiya launch sequence during the abortive 29 October 1988 attempt to launch the Buran shuttle. The Energiya fueling/defueling system AI package reportedly is optimized to detect and compensate for some 500 different types of fueling/defueling faults.

According to open-source literature, the Soviets used the French-developed programming language known as Prolog to develop on-board system software for the Buran vehicle—which flew its first orbital mission—unmanned—in late 1988, using automated flight control managed by remote ground control. Prolog is used to program AI systems, implying that AI techniques are used to enhance mission-control fault tolerance on the Buran [redacted]

CASE Technologies

The Soviet software research community has mastered a variety of techniques for the automated production of software. Soviet civilian and defense industries since the late 1970s have been gradually assimilating CASE products. Soviet effectiveness in developing CASE techniques stems from a number of competent mathematicians and systems analysts at key computer science institutes. Soviet CASE achievements include:

- *Prometey*: A large-scale CASE system, which, [redacted] includes automated techniques for developing software for strategic and tactical missile systems. Distributed by the Ministry of the Radio Industry, Prometey utilities are designed to automate the development and life-cycle maintenance of various types of software having up to 3 million lines of program code. Prometey utilities also implement Rada—the USSR's version of the NATO-standard military-purpose programming language Ada.

- *R-technology*: A structured-design software engineering methodology developed in the early 1970s. [redacted] R-technology has been used by software developers in the USSR's strategic missile industries. The Soviets claim that R-technology enables software professionals to electronically "draw" on a computer screen the algorithmic design of the software, which is then automatically mapped to a compiler that generates executable object code.

- *AI and CASE*: Soviet industry has access to several AI-augmented CASE environments developed as research projects since the 1970s. These prototypes are serving as technology feasibility demonstrators for the development of practical AI-augmented CASE products for the 1990s.

General Industrial Applications

The Soviets, according to Western experts, have made good progress in software for some general industrial applications. Western experts rate these Soviet products as functionally equivalent to or better than similar Western software:

Acquisition of Non-Communist Technology

As the Soviets press ahead with their software productivity initiative, we expect them to intensify efforts to obtain foreign software technologies and know-how. The Soviet covert effort presents certain challenges to technology denial efforts not encountered in other technical domains. These challenges occur because software productivity enhancing measures consist largely of methodological practices and conceptual techniques that are difficult or impossible to subject to trade restrictions or to classify as national security information—at least before such methodologies are "captured" in tangible commercial products. Moreover, even when commercialized, software can be reproduced without having to make substantial capital investments in high-technology physical plants. Software piracy is easy, effective, and inexpensive to undertake covertly—and at far less risk and cost by comparison with what is involved with stealing hardware (see inset on page 9)

The USSR's commercial-joint-ventures policy introduced in 1987 makes it easier for Soviet industrial enterprises to deal directly with foreign industries. This policy, which is rapidly evolving, is proving to be a principal conduit for Soviet access to Western software development technologies. As a byproduct of Soviet efforts to implement commercial joint ventures (R&D, manufacturing, and marketing) with Western industries, increasing numbers of Soviet systems analysts, software engineers, and programmers—including defense industry personnel—have begun to travel around the world to promote joint software ventures. We also expect that an increasing number of Soviet software specialists from scientific and academic establishments will attempt to work with software productivity experts abroad under the guise of academic exchanges.

The rapid political and economic changes now under way in the USSR and Eastern Europe almost certainly will accelerate Soviet access to Western software technologies. Western software industries are at the forefront of efforts to develop markets in the USSR. Companies and individuals in Eastern Europe are already working closely with Western software companies.

Examples of Western Software Technology Transferred to the USSR

Acquisition of foreign software engineering methodologies, technologies, and modeling packages in the late 1970s reinforced Soviet efforts in several militarily and economically significant ways. In general, these acquisitions of know-how and technology saved the Soviets years of applied research that otherwise might have delayed the implementation of advanced technologies in a wide variety of military equipment introduced in the mid-to-late 1980s

[redacted]

Other examples of Soviet time- and cost-saving exploitation of Western-origin software technologies have included the use of:

- *Simulation software to optimize designs for strategic ballistic missile motors.*
- *Mathematical models used to simulate the performances of ground and space-based radars for air/space defense.*
- *Algorithms to build applications software for air-to-air missile guidance systems.*
- *Data or source code for developing software for terrain-mapping radars for use with cruise and ballistic missiles.*
- *Utilities programs that were used as tools to develop command and control system software.*

In addition to enhanced Soviet liaisons with software industries in NATO countries, we anticipate heavy R&D interactions between the USSR's software community and the technically proficient software R&D communities in countries such as India and Brazil. Analysis [redacted] indicates the GKVTI will be the focal point for Soviet participation in these efforts. The interactions between Soviet industrial ministries and India's and other countries' software R&D communities are expected to intensify by 1990. The Japanese and Singaporean software R&D communities are, according to open-source literature, approaching world-class competence in some facets of software engineering operations. We believe that both countries are earmarked by the Soviets for intensified lobbying to promote the joint development of all types of software technologi..

Furthermore, the growing number of countries that are capable of developing commercially successful software industries (for example, Brazil, India, South Korea, and Singapore) are not necessarily disposed toward international regimes to restrict the flow of technology to the USSR or Eastern Europe. Under these circumstances, the restrictions of the Coordinating Committee on Export Controls (COCOM) that have thus far slowed Soviet and East European access to Western software technologies may gradually become less effective, unless other countries join with COCOM and enforce trade restrictions

At present, we believe that the best defense against Soviet acquisition—legal or illegal—of militarily significant software technologies is the degree to which developers employ measures to prevent unauthorized access to the product source code [redacted]

Outlook

The software productivity initiative, coupled with intensified efforts to acquire Western technology, is the USSR's best hope to maintain competitiveness with the West in computer-dependent military systems; to become more self-sufficient in its ability to modernize its military and civilian industries; and to establish itself as a serious industrial competitor in international markets for technology driven products of all types. The Soviets, through their software productivity initiative, almost certainly will make good progress in addressing some of their problems:

- They will increase capital investment in software engineering technologies.
- The influence of the USSR's software R&D community over the stagnant software industry will grow.
- A centralized approach to applying standards and norms, combined with CASE, will make software production more efficient.
- The Soviet software work force will increase substantially.

On the other hand, the software productivity initiative offers little hope against other challenges. The Soviets lack experience in operating customer-oriented businesses. Soviet management philosophies reward the maintenance of existing product lines at the expense of new products. Moreover, deficiencies in computer systems networking will continue to stifle Soviet software development. Even if the Soviets forcefully implement wide-area networks and local-area networks, they will still lack experience in operating the telecommunications infrastructure necessary to take full advantage of modern networking technologies.

Our analysis of open-source literature implies that the Soviets have a long way to go before their telecommunications industries can manufacture and service the technologies inherent to establishing and maintaining a modern civil telecommunications infrastructure. The USSR's enduring tradition of compartmentation, secrecy, and consequent need to control access to communications technologies further impedes Soviet efforts to modernize telecommunications. Under these circumstances, we believe that the Soviet software community will not have access to local- and wide-area networks equivalent in quality and efficiency to those used today in the West until well after the year 2000.

Thus, despite the considerable talent and effort the Soviets will apply to their software productivity initiative, we doubt that the USSR will be able to close the roughly 10-year gap between it and its foreign competitors by the turn of the century. Most likely the Soviets will be hard pressed to keep the gap from widening; the pace of progress in the West is great and growing more rapid

All in all, the deck is stacked against the Soviets in their desire to build a software infrastructure that can some day be technically competitive with industries in the United States, Western Europe, and Japan. Although the Soviet S&T leadership fully recognizes fixes need to be made, it confronts an entrenched bureaucracy in the software industry that is not inclined to modernize at more than a snail's pace. Failure to close the software gap will keep the Soviets at a significant disadvantage in competing with other countries in the development and production of advanced weapons and military support systems.

Fruits of the software productivity initiative, coupled with the output of emerging pockets of excellence, nonetheless will give the Soviets important new military and economic capabilities in the years ahead. The software R&D base the Soviets will have in place by the year 2000 should approximate that available to US, Japanese, and West European software engineering communities in the late 1980s. The availability of such advanced technologies to the USSR's defense industries in the late 1990s would constitute part of the enabling technologies base essential to developing the computer-software-dependent weapons, reconnaissance and surveillance systems, command and control systems, communications, and logistic support systems that the USSR is expected to begin developing in the 14th Five-Year Economic Plan (1996-2000).

The Soviet software R&D community is prototyping, and beginning to deliver for operational (industrial) use, AI-CASE environments that can be used to create advanced software for fault-tolerant, multipurpose computer-integrated-manufacturing environments in which networks of "smart" multipurpose robots and machine tools almost completely supplant workers for certain types of high-precision operations. Industries supporting military R&D and production are likely to be the first to assimilate such new CASE technologies—particularly to manufacture new microelectronics, optics components, inertial instruments, and other precision equipment

With respect to development of software for large scientific parallel-processing systems—essential to some military sponsored research and important dual-use technologies research—the Soviets, by the turn of the century, may be at or near the Western state of the art in research. In some areas of software research for AI technologies the Soviets also may approach the West's level of achievement. In a handful of critical application areas—such as use of software-intensive AI expert systems for fault-tolerant computers used with the USSR's space shuttle system—the Soviets may remain only three to four years behind Western applications.